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Report to

Massachusetts Technology Park Corporation

March 1987

Business Plan for the Massachusetts Materials Center

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ACKNOWLEDGEMENTS

We would like to thank the MTPC Advisory Committee on the Massachusetts Materials Center, MNS Consultants, Inc., and Dr. Bruce S. Old for their assistance on this project. We would also like to thank the numerous industry representatives, and university administrators and faculty members for their time and insights on the proposed Center. Of course, final responsibility for this report, including any errors or omissions, rests with Arthur D. Little, Inc.

TABLE OF CONTENTS

Page No.

I. EXECUTIVE SUMMARY 1

II. INTRODUCTION AND RATIONALE 6

III. MISSION STATEMENT 9

IV. PROGRAMS 10

V. MANAGEMENT PLAN 17

VI. OPERATING PLAN 24

VII. MARKETING PLAN 31

VIII. FINANCIAL PLAN 35

IX. IMPLEMENTATION PLAN 44

APPENDIX A 47

APPENDIX B 54

APPENDIX C 60

APPENDIX D 64

I. EXECUTIVE SUMMARY

Arthur D. Little, Inc., has been retained by the Massachusetts Technology Park Corporation (MTPC) to assess the feasibility of the Massachusetts Materials Center (MMC) and to develop a business plan for the proposed Center. Based on a comprehensive study, this document constitutes the business plan for the Massachusetts Materials Center.

There is a general consensus among representatives from industry, universities and government on the basic mission of the Massachusetts Materials Center:

> **Accelerate the pace of industrial innovations in materials and materials processing through industry-driven applied research that bridges the gap between basic research and product development.**
>
> **Strengthen research capabilities within universities in the area of advanced materials by providing access to sophisticated processing and characterization equipment.**
>
> **Enhance materials science and engineering education by involving graduate students, undergraduates and company employees in multi-disciplinary research efforts conducted within state-of-the-art facilities.**

These statements should guide the activities of the Massachusetts Materials Center. Programs should be structured, and, in the final analysis, evaluated based on these broad statements of purpose.

The activities of the MMC should focus on three programs: Applied Research Program, Shared Equipment Program, and Educational Program.

- Applied Research Program -- The objective of the applied research program should be to develop new or improved materials and processing technologies that can be used by industry to lower costs, improve performance or develop new products. In this way, the Center will contribute to improving productivity and enhancing the competitive position of participating companies. Given the significant presence and growth potential of the electronics, computer and telecommunications industry in Massachusetts; its specific research interests as expressed in interviews with corporate executives; and the strengths of the state's colleges and universities in this area; we feel that the MMC should initially focus on research relevant to this broadly-defined industry. In keeping with this initial focus, MMC should consider launching a major research program to address materials and materials processing requirements associated with electronic materials, particularly in the area of integrated optics. Other

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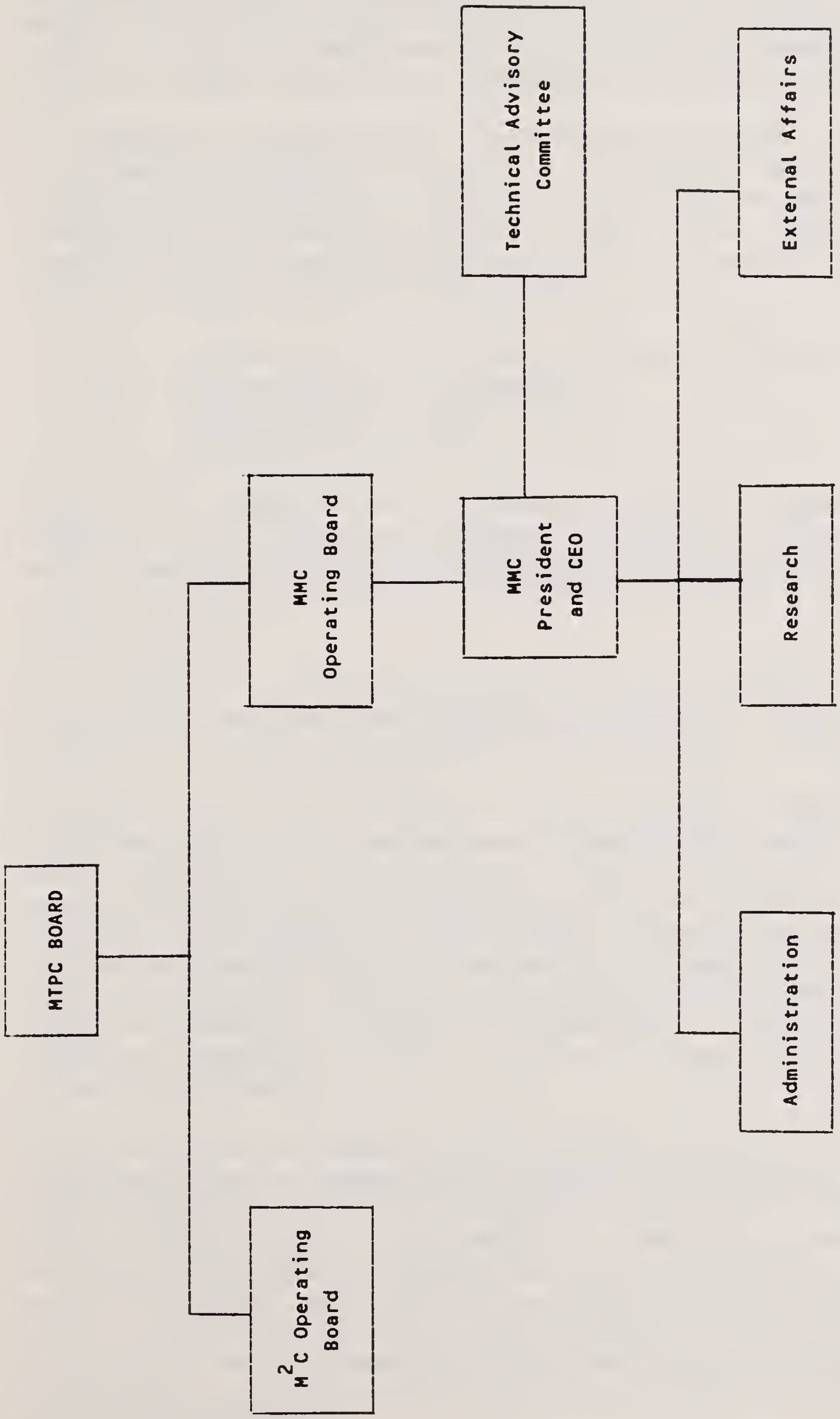

FIGURE 1 BASIC ORGANIZATIONAL STRUCTURE

management positions are the Chief Executive Officer and the Vice Presidents responsible for each of the major units. The staffing of the Massachusetts Materials Center will be critical to its success. MMC should have a permanent staff, consisting of exceptionally qualified administrative, research and technical personnel. This core staff should be supplemented by industry researchers, university faculty, federal laboratory researchers and graduate students.

We recommend that the Center lease existing facilities and renovate to suit particular needs. This will result in lower initial capital costs; more importantly perhaps, it will allow MMC to become fully operational in a shorter period of time. The 25,000 square feet of laboratory space required for research in electronic materials should consist of four principal components:

A. Crystal growth, slicing, grinding, and polishing
B. Characterization of wafers
C. Preparation of active layers
D. Prototype fabrication.

Within the laboratories, equipment should represent the highest quality, state-of-the-art equipment available. Office, meeting rooms and storage should total an additional 25,000 square feet. MMC should lease an additional 20,000 square feet to allow for expansion into new research fields.

In deciding on an optimal location for the Center, the MTPC Board should use well-defined selection criteria, with an emphasis on proximity to relevant university and industrial activity.

MMC will have to be marketed to three groups: industry, universities and government. The Massachusetts Materials Center should actively seek industrial participation from material and component manufacturers, equipment manufacturers and end users of components. Serious consideration should be given to not pursuing the concept any further without a clear commitment of funding and personnel from industry in Massachusetts. MMC should have a two-tiered structure with two levels of corporate membership -- sponsoring members and affiliate members -- with different forms of participation and financial obligation.

MMC will need to identify and secure the up-front commitment of individual faculty members with expertise in electronic materials and with interest in participating in the MMC applied research and educational programs. In addition, MMC will need to establish suitable arrangements governing the nature and method of participation on an individual and institutional basis. MMC should emphasize the scale of research activities envisioned for the Center, the presence of sophisticated processing and characterization equipment, and the opportunity to work with industry on critical material and material processing problems.

The scale of activities envisioned for the Massachusetts Materials Center will entail considerable up-front capital, as well as funds for on-going operations. Given an emphasis on electronic materials, the Massachusetts Materials Center will require an initial capital outlay of $17 million for equipment (including clean rooms). The initial annual operating budget should be on the order of $170,000, growing to $5 million, with a total operating budget of $24 million through 1992. Although there will be some overlap in equipment, primarily in materials characterization, a similar level and pattern of expenditures will be required for expansion into areas outside of electronic materials.

Chapter 466 of the Acts of 1984 authorizing the establishment of MMC stipulates that the state will grant $20 million for facilities and equipment provided that this sum is matched by industry and/or the federal government. While industry is likely to contribute significantly toward operating expenses, it is unlikely that industry will contribute sufficient funds up-front to cover initial capital outlays. Therefore, MMC will have to secure significant federal funding in the form of both capital and on-going financial support to be viable. Given the structure of the state's matching grant, MMC will not be able to cover its initial capital and operating costs without a major injection of federal monies or in-kind support, e.g., a donated building.

One promising avenue for securing the level of funding required is through DARPA. DARPA is in the process of exploring a major new initiative in the area of materials processing. In a parallel effort, both the Materials Research Council and the R&D Committee of IEEE have recommended the establishment of a national research institute focusing on opto-electronics with a strong emphasis on materials and prototyping. DARPA is considering funding such an institute, providing monies for facilities, equipment and operations for five to seven years. DARPA, and the companies involved to date recognize the critical importance of locating the institute in an area that has a strong technology base. Massachusetts clearly has both the level of research and industrial activity to meet this requirement and would stand in a good position to attract DARPA funding. An emphasis on opto-electronics would respond to the expressed interests of companies in Massachusetts. Moreover, DARPA or an equivalent level of funding, would serve as a needed catalyst to establish the Center, and enable MMC to expand its focus and activities to recognize that MMC will need to be vigilant that DARPA-funding does not result in a situation where research efforts are directed toward government objectives at the expense of industrial concerns.

II. INTRODUCTION AND RATIONALE

Arthur D. Little, Inc., has been retained by the Massachusetts Technology Park Corporation (MTPC) to assess the feasibility of the Massachusetts Materials Center (MMC) and to develop a business plan for the proposed Center. The assignment was divided into three phases:

- Concept Review
- Market Assessment
- Business Plan Development

The Phase I Report, Review of the Proposal for the Establishment of the Massachusetts Materials Center, was issued in September, 1986. The Phase II Report, Analysis of the Nature and Level of Interest in the Massachusetts Materials Center, was submitted in January, 1987. Both reports laid the foundation for the business plan presented below. It is important to recognize that both the prior reports and the business plan are based on a comprehensive study, involving:

- Interviews with corporate executives of companies located within and outside of Massachusetts

- Interviews with administrators and faculty members within universities and research centers in the Commonwealth

- Interviews with legislators and representatives of state economic development agencies

- Interviews with representatives of relevant federal agencies, e.g. National Science Foundation (NSF), National Bureau of Standards (NBS), Department of Energy (DOE), Congressional Office of Science and Technology, and DARPA.

- An extensive review of the experience of other state technology development initiatives and university-based research programs

- Expertise of industry and technology experts within Arthur D. Little, Inc.

- Numerous planning meetings with the MTPC Advisory Committee on the Massachusetts Materials Center.

This work has led to the refinement of the overall MMC concept and specific programmatic, organizational and operational characteristics. The basic rationale underpinning the MMC can be expressed as follows:

- The industries in which advanced materials play an important role are large and growing rapidly. Electronic components represent a world market of over $60 billion with annual

growth of 10-15 percent expected through the end of the decade. Structural ceramics, currently a small segment of the ceramics market, is expected to grow 10-15 percent by volume through 1995. Advanced composites represent a world market of over $1.3 billion with expected future growth on the order of 15-25 percent per year. The market for high performance plastics is expected to grow at an annual rate of 15-20 percent.

- These industries are facing increasing competition from abroad. Industry and government are raising alarms over heightened international competition. As an example, a recent study by the Panel on Materials Science under the auspices of the National Material Advisory Board calls attention to the fact that "Japan is taking the lead in several key areas of electronic material fabrication." These concerns were mirrored in our discussions with companies in Massachusetts. Moreover, companies point out that the speed at which new technologies are introduced into the marketplace lies at the core of this competition.

- The potential erosion of the United State's traditional strength in materials and materials processing is a national problem requiring a level of effort that is national in scope. This same panel noted that research institutions in the United States lead the world in basic materials science and physics research and calls for universities and federal laboratories to respond to the challenge. Although many programs have already been initiated throughout the country, efforts are fragmented. No program has yet achieved national recognition as the Center for materials and materials processing.

- Universities and federal laboratories in Massachusetts are at the forefront of basic research. In addition, some of the State's universities have established very close ties to industry, working much more within an applied orientation. However, companies require support that is on a higher scale and that is qualitatively different from that which is currently available through universities and other institutions. In particular, industry is looking for assistance in developing and applying advanced material processing technologies. This requires a concerted, large-scale applied research effort. Companies and universities in Massachusetts recognize that the development of needed materials and materials processing technologies demands a level of capital expenditures and technical skills that few firms or universities can afford on their own.

- Accelerating the pace of innovation requires a new type of organizational structure that addresses the expressed needs of companies. This organization would draw on the considerable base of expertise and resources available within colleges and universities and focus it on industry-driven applied research problems. In general, companies and universities in Massachusetts support the idea of creating this new institution -- the Massachusetts Material Center (MMC).

- It is likely that only one or two Centers, each with a principal focus on a different class of materials, will be established and supported at the required level in the United States in the foreseeable future. For this reason, and for reasons related to the program's effectiveness, MMC will need to carve out a niche within the broad materials arena. Given the level and pattern of industrial interest already expressed, and the expertise and resources resident within the State's colleges and universities, Massachusetts stands in a good position to take the lead in electronic materials and use this base to expand into additional areas, e.g., composites, metals, ceramics and polymers.

III. MISSION STATEMENT

Interviews conducted under Phases II of our assignment, revealed considerable interest in the MMC concept on the part of industry, academia and government. There is a general consensus on the basic mission of the Massachusetts Materials Center:

> **Accelerate the pace of industrial innovations in materials and materials processing through industry-driven applied research that bridges the gap between basic research and product development.**
>
> **Strengthen research capabilities within universities in the area of advanced materials by providing access to sophisticated processing and characterization equipment.**
>
> **Enhance materials science and engineering education by involving graduate students, undergraduates and company employees in multi-disciplinary research efforts conducted within state-of-the-art facilities.**

These statements should guide the activities of the Massachusetts Materials Center. Programs should be structured, and, in the final analysis, evaluated based on these broad statements of purpose. However, it is important to develop a set of objectives that make the actual responsibilities of MMC clear, and provide specific guideposts for on-going monitoring and evaluation. The specific objectives and role of MMC in relation to each of these three statements are discussed below with respect to individual programs.

IV. PROGRAMS

Based on an assessment of the market presented in our Phase II Report, Analysis of the Nature and Level of Interest in the Massachusetts Materials Center, the activities of the MMC should focus on three programs: Applied Research Program, Shared Equipment Program, and Educational Program.

A. Applied Research Program

Research conducted under the auspices of the Massachusetts Materials Center should be targeted in certain areas:

> **The objective of the applied research program should be to develop new or improved materials and processing technologies that can be used by industry to lower costs, improve performance or develop new products. In this way, the Center will contribute to improving productivity and enhancing the competitive position of participating companies. Given the significant presence of the electronics, computer and telecommunications industry in Massachusetts, its prospects for future growth, and the strengths of the state's colleges and universities in this area, we feel that the MMC should initially focus on research relevant to this broadly-defined industry. In keeping with this focus, MMC should consider launching a major research program to address materials and materials processing requirements associated with electronic materials, particularly in the area of integrated optics. Other research efforts might center on meeting the needs of the hybrid circuit industry, particularly in the area of packaging materials. The emphasis on electronic materials should extend at least over the next five years. As MMC becomes established, it should expand into new areas, e.g., composites, metals and metal matrix composites, ceramics, and polymers.**

As part of our assignment, we conducted interviews with 28 corporate executives, representing 19 companies in Massachusetts. The companies were chosen to reflect the overall composition of the "materials industry" in Massachusetts. The purpose of these interviews was to assess the needs of the "materials industry" in the Commonwealth, and identify the areas which industry felt should be addressed by the Massachusetts Materials Center. Table 1 presents the pattern of interests among the companies interviewed. More than half of the companies were interested in electronic materials. Specific interests within the broad area of electronic materials varied. Table 2 demonstrates that more than half of the firm concerned with electronic materials had an interest in opto-electronics and fiber optics. Roughly a third were interested in the area of packaging. It should be noted that many companies expressed interest in more than one area. Moreover, in some instances there was a great deal of overlapping interests, e.g., metals and opto-electornics in sensor applications.

TABLE 1

PERCENTAGE OF COMPANIES EXPRESSING INTEREST IN DIFFERENT CLASSES OF MATERIALS

Class of Material	Percentage[1]
Electronic Material	53%
Metals[2]	26%
Ceramics	21%
Composites	16%
Polymers	16%

1. Percentages add to more than 100% because some companies expressed interest in more than one class of material.

2. Includes metal-matrix composites

Source: Arthur D. Little, Inc., based on company interviews.

TABLE 2

SPECIFIC INTERESTS OF COMPANIES CONCERNED WITH ELECTRONIC MATERIALS

Area of Interest	Percentage[1]
Opto-Electronics[2]	55%
Packaging	36%
Thin Films	18%
Other or Not Specified	27%

1. Percentages add to more than 100% due to multiple responses by some companies.

2. Includes optical systems and fiber optics.

Source: Arthur D. Little, Inc., based on company interviews.

Although the final determination of MMC's specific research agenda will be made by the person selected to be the President and Chief Executive Officer (CEO), MMC should initially address the area identified as a priority -- electronic materials, particularly integrated optics. This emphasis parallels the interests and strengths of the States colleges and universities as reflected in interviews with 39 administrators and faculty members.

Integrated optics is the term used to describe the new generation of opto-electronic systems in which wires and cables are replaced by light-waveguiding fibers and integrated circuits are replaced by integrated optical circuits (IOCs). Integrated optics will serve as a principal building block for future computers, telecommunication systems and advanced manufacturing technologies. Practically every function performed by individual electronic circuits have their analog in the optical domain, e.g., switches, amplifiers, filters, modulators and logic gates. It is likely that integrated optical circuits will be found in numerous commercial products. Some of these applications are near-term, e.g, optical toll switches, others are more long-term. Fully integrated optical computers may require ten years of further development prior to market introduction. Research conducted under the auspices of MMC in this area should center on developing appropriate materials, waveguide concepts and fabrication techniques for integrated optical circuits. Research should concentrate on non-silicon materials, including gallium arsenide, indium phosphide, cadmium telluride, and other III-V and II-VI compounds and their alloys. The research program should include projects spanning the range from bulk crystal growth to prototype fabrication. The importance of prototyping should be emphasized. Although the orientation of the MMC is on materials and materials processing, it will be critical for the center to prove concepts through prototype applications. As part of the research program, MMC should define the resources which firms will require to adopt technologies or techniques developed under the auspices of the Center.

The other research area that came up quite frequently in our market assessment was packaging. There are some challenging problems in packaging; some of these relate to the current structure of the market, others relate to technical matters. The Japanese, i.e., Kyocera, dominate the market for simple ceramic packaging based on aluminum oxide and lead in more complex packaging for VLSI circuits. MMC will need to define its particular niche carefully. Given the strengths of universities and the local industrial base, MMC should focus on polymeric packaging and packaging for complex hybrid circuits.

The specific research agenda should be established by the CEO of MMC, in conjunction with a Technical Advisory Committee, and with the approval of the Operating Board. Given the proposed orientation of MMC, the Center should not have a primary basis in the type of

research projects traditionally funded by the National Science Foundation, Department of Energy, DARPA, etc. These projects tend to be discrete, highly-competitive, one- to three-year efforts subject to peer review primarily by the academic community. These projects typically involve basic research. However, this does not rule out funding from these agencies entirely. As discussed below (Section VI.C), certain agencies have established research and development programs that are essentially oriented toward strengthening the research infrastructure in the United States through the creation of research centers. Particularly in the early stages of development, MMC should seek "center" funding, which could then be complemented by project-specific funding from federal sources. Given this type of "center" funding, the Massachusetts Materials Center would have a great deal of latitude in setting its own research agenda in response to market needs and technological advancements.

Although MMC should emphasize electronic materials during its initial years of operation, activities should _not_ be restricted to this class of materials. Given appropriate funding, MMC should sponsor and undertake research efforts in other materials, laying the foundation for incorporating additional major research programs into MMC in later years. Moreover, under the center type of funding, firms may cooperate in bilateral agreements with each other or with a university participant, assuming that the research activities under such agreements are consistent with the agreed-upon research agenda. The intent is to foster a variety of interactions and collaborations among all parties -- industry, universities, and MMC.

Further, research conducted under the auspices of the Massachusetts Materials Center should _not_ be restricted to the MMC facility alone. Certain projects should be conducted within university laboratories. In general, as research becomes more applied, the actual research effort should occur within the MMC facility and be directed by MMC staff.

B. Shared Equipment Program

Increasingly, companies and universities are facing significant constraints associated with the tremendous cost of research. MMC can assist in offsetting these costs through the provision of specialized equipment:

> The objective of the shared equipment program is two-fold -- strengthen research capabilities within universities and industry, and more directly lower the high capital and operating costs associated with materials and materials processing research. The Massachusetts Materials Center should house sophisticated processing and characterization equipment related

> to bulk crystal growth, wafer fabrication, ion implantation, thin film epitaxy, thin film deposition, and prototype device fabrication. In addition to serving the needs of MMC research, itself, much of this equipment should be made available to universities and industry for research purposes on a fee-for-use basis.

Research is becoming more capital-intensive; in a similar vein, the useful life of equipment is becoming shorter. This is putting enormous financial pressure on both industry and academia. The capital outlays, and operating and maintenance costs associated with materials research is beyond the financial capabilities of most universities and individual companies. The Massachusetts Materials Center should respond to this need by making equipment available through a centralized facility. (MMC facilities and equipment are detailed below in Section V.B.). A centralized facility offers a number of advantages. It takes advantage of economies of scale, lowering the per unit costs associated with the production and analysis of materials. It also facilitates access by individual universities and companies, avoiding potential problems associated with institutional "ownership" of equipment.

University faculty and graduate students would have access to this equipment through participation in MMC-sponsored collaborative research projects. In addition, a certain percentage of time could be set aside to allow university faculty and graduate students to use equipment for their own experiments. Industry could gain access to equipment in a parallel manner. Industry should be allowed to use equipment for proprietary research on a fee-for-use basis. However, in setting appropriate policies, the CEO and Operating Board should be extremely careful to structure the arrangements with industry in a way that does not compete with private analytical laboratories. This is especially relevant to surface analysis.

C. Educational Program

The whole arena of materials science and engineering is evolving rapidly, increasingly requiring individuals with experience and expertise that cuts across a number of disciplines, e.g., chemistry, chemical engineering, physics, electrical engineering, industrial engineering, and solid state physics. The Massachusetts Materials Center should respond to this need.

> The objective of this program should be to strengthen the educational process with respect to materials science and engineering. MMC should coordinate, facilitate and sponsor multi-disciplinary educational programs aimed at graduate students, undergraduates and company employees. MMC should not, itself, become a degree granting institution. The principal vehicle for MMC's direct participation in the educational process

> **should be involving students and employees in on-going research efforts within MMC's own state-of-the-art facilities. The Center should also assist in developing relevant continuing education programs in conjunction with the State's colleges and universities. In addition, the Center should sponsor conferences and seminars.**

MMC should complement the vast educational resources present within the state by offering laboratory experience to students and company employees. MMC should establish lab courses, theses, and work cooperative programs in conjunction with universities and colleges in Massachusetts. Through its research program, MMC should provide financial support to students participating in MMC-sponsored research.

MMC should also sponsor annual conferences and quarterly seminars as part of its educational mission. These meeting would focus on issues of interest to the materials industry, drawing on the findings of research conducted under the auspices of the Center.

V. MANAGEMENT PLAN

There is a general feeling that universities are not the appropriate institutions for the type of research discussed above because of their emphasis on fundamental scientific problems and their departmental structure. Our interviews revealed that many companies are disillusioned with many of the university-based research consortia with which they have been involved. They do not see sufficient tangible benefits to justify their continued participation in many of these university-based research consortia. While faculty and graduate students are clearly critical to the success of the MMC, it was generally felt that the Center should be independently managed -- affiliated, but not part of a departmental or university structure.

If the Center is to function as designed, it is important that the organization and governance structures be consistent with stated objectives and intended outputs. Figure 2 depicts the recommended organization for the Massachusetts Materials Center. The proposed structure is designed to provide the Center enough flexibility to conduct research in areas currently considered of highest priority, and to respond in a timely fashion to newly identified industrial needs. This flexibility and freedom of action is essential in a technical environment as dynamic as the one in which the Center must operate. At the same time, the structure will ensure that MMC is accountable to major participants and funders -- industry, universities, and state and federal government.

A. Governance

The Massachusetts Technology Park Corporation is charged with the responsibility for establishing the Massachusetts Materials Center. To date, the MTPC has had to deal with only one research entity, the Massachusetts Microelectronics Center (M^2C). Consequently, the Board has been heavily oriented toward the microelectronics industry. Because of the qualitative technical differences between the two Centers, as well as their different histories and purposes, we propose an expansion of the governance structure for MTPC and a separate, subsidiary structure for MMC.

1. Corporate Board -- The MTPC Board should serve as the corporate governing body for an umbrella structure, which includes both M^2C and MMC. The membership of the MTPC Board should be expanded or altered to include individuals with diverse technical backgrounds and interests. The structure should also be flexible to allow additional expansions or membership modifications in the event of decisions to establish additional research centers under the general framework of MTPC. The MTPC board should provide broad oversight of both centers through review of the decisions of the operating boards, particularly those involving the

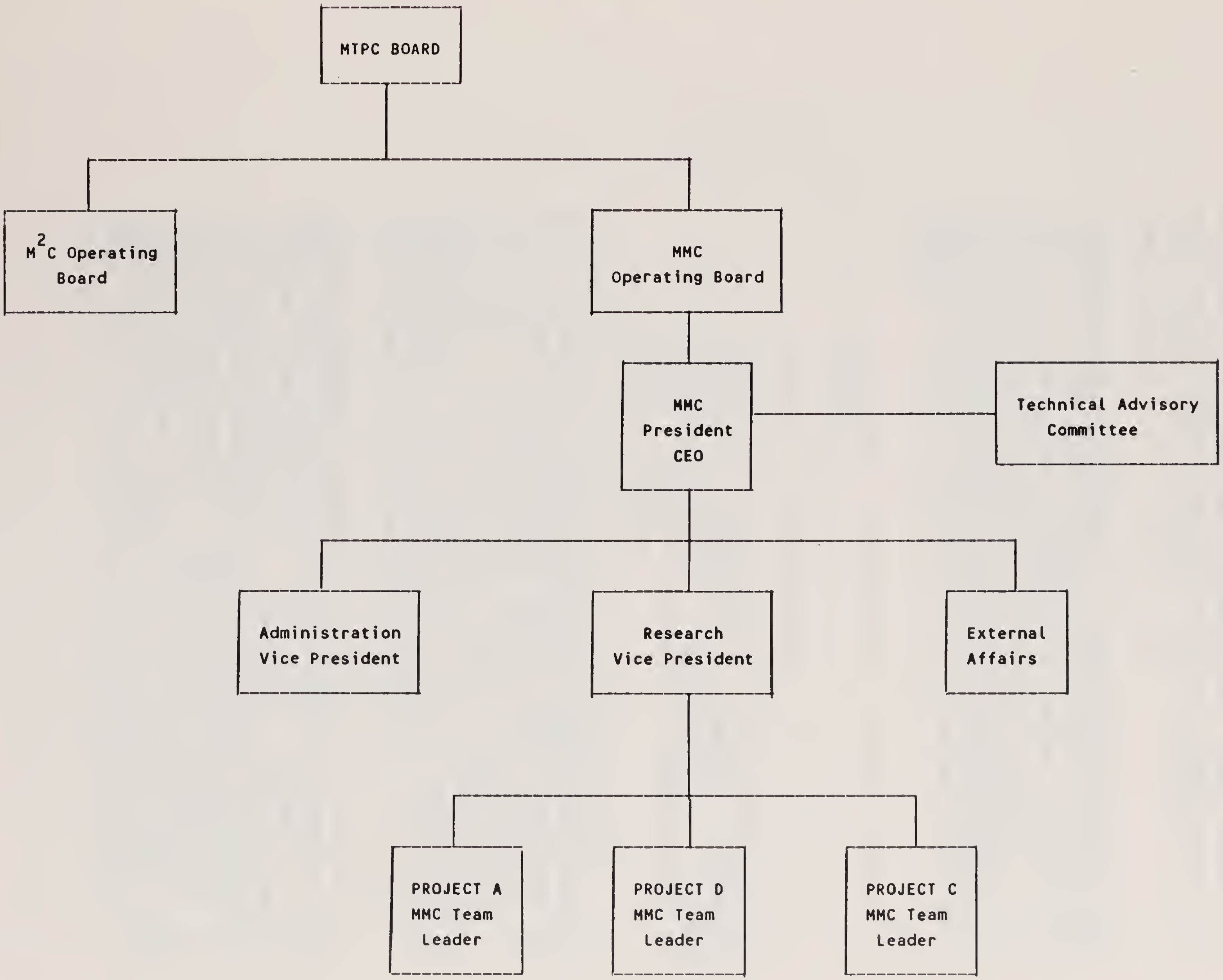
MTPC BOARD
M^2C Operating Board
MMC Operating Board
MMC President CEO
Technical Advisory Committee
Administration Vice President
Research Vice President
External Affairs
PROJECT A MMC Team Leader
PROJECT D MMC Team Leader
PROJECT C MMC Team Leader

FIGURE 2 DETAILED ORGANIZATIONAL STRUCTURE

general direction of programs and associated annual budgets. The Board should have primary responsibility for evaluating both the M^2C and the MMC. Finally, the Board should serve as the major liaison between the Centers, the Governor, the State Legislature, industry, and universities in the Commonwealth.

2. Subsidiary Operating Boards -- Subsidiary Operating Boards should be appointed for both M^2C and MMC. These Boards should be comprised primarily of senior industry and university representatives with technical expertise in the areas of greatest interest to their respective Centers. The Operating Boards should be appointed by the MTPC Board. The specific authority reserved for the Operating Boards should include:

   - Appointment and termination of the CEOs of the Centers
   - Budget review and approval
   - Review and approval of general policies for the Centers, including those governing industry-university relationships, research agendas, linkages with outside organizations, and personnel policies

   The MMC Operating Board should be relatively small -- five to nine members -- with the majority coming from industrial participants. The remaining members should be drawn from the universities and federal laboratories associated with the Center. At least one additional member should be appointed as representative of the Commonwealth of Massachusetts. Operational issues, such as terms of office and rotation of the chairmanship, should be worked out early and included in the bylaws for the Center.

3. Technical Advisory Committee -- In addition to the Operating Board, MMC should have a Technical Advisory Committee which includes representatives from all industrial and institutional participants. The members of this Committee should not necessarily include the Directors for Research at participating companies. Rather, individuals should have personal experience in areas directly relevant to the research programs of MMC, e.g., the company's best researcher in, for example, integrated optics. While this group will not have specific governing authority, it provides:

- A direct voice for all industrial and institutional members in the operations of the center

- Immediate feedback on research needs and conditions in the industry

- Inputs from industry and university participants on research findings and potential applied research projects.

The Committee will advise the CEO on appropriate directions for the research efforts and will also assist the Operating Board in evaluating Center performance.

B. Functional Organization

Although much of the technical work in which MMC engages will be project- or task-oriented, we recommend that the operating organization be established on a functional basis, with major departments for research, administration, and external affairs. The critical senior management positions are the CEO and the Vice Presidents responsible for each of the major units.

1. Chief Executive Officer -- The CEO should have full responsibility for all operations at the Center. The individual selected must have a sound scientific reputation, as well as extensive industrial experience, a solid appreciation of materials research, and an understanding of university research activities. The CEO should be responsible for developing and maintaining strong relationships with industry, academia and government. The CEO, in conjunction with other staff members, should undertake fund-raising, long-range planning, formulate specific institutional objectives and associated policies, prepare annual plans and budgets, and be responsible for the financial integrity of the institution.

2. Research Department -- This unit should be headed by a Vice President with significant scientific expertise and industrial research experience. The VP for Research should be responsible, under the CEO, for directing and coordinating research activities, both those conducted at the center by staff scientists and those conducted at other sites (industrial labs and universities) under the auspices of the Center. The overall research agenda will provide general direction, but the VP Research will develop detailed research programs and budgets within that framework. Specific areas of authority should include the selection of the scientific staff, identification of equipment and space

needs, and coordination of research activities among the cooperating companies and institutions.

3. Administrative Department -- All internal support and financial functions should fall under the purview of the Vice President for Administration and Finance. Responsibilities should include planning and budgeting, purchasing, personnel management, financial administration, legal affairs, patent/licensing policies and facilities management. The Vice President should have experience in a scientific research environment, either in an industrial corporation with a strong research component, or in university administration. The individual must be a competent administrator, and a strong manager, who understands the needs of R&D personnel and organizations. He or she must also be familiar with the practices of major funding agencies, and the accountability requirements for research grants and contracts.

An additional functional unit -- External Affairs Department should also be established soon after MMC begins operations. A major factor in the success of the MMC will be the links between the Center and outside individuals, agencies, corporations and other research units. The External Affairs Department should oversee publication of Center newsletters or scientific notes, and will assist research staff with publications or other communications activities. The department head must have substantial experience in marketing and other communications, and be able to coordinate the activities of diverse groups.

Each of these major departments will have subordinate units which will be developed after the basic structure and division of responsibilities have been established.

C. Authority, Reporting, Internal Relationships

The formal by-laws and operating policies of MMC should address a number of issues related to governing authority, reporting and internal relationships. Specific recommendations include:

1. The MTPC Board should retain the ultimate responsibility for MMC operations. However, it is recommended that they delegate the oversight function and on-going supervision of MMC to the MMC Operating Board. The MMC Operating Board would report to the MTPC board semi-annually on the performance of the center, using evaluation criteria jointly established by the two groups. The budget approval process is an appropriate time for this evaluation and report.

- MMC royalties should be distributed, in part, to relevant research personnel. The remainder should be retained for reinvestment into MMC.

VI. OPERATING PLAN

A. Staffing

The staffing of the Massachusetts Materials Center will be critical to its success:

> **The Massachusetts Materials Center should have a permanent staff, consisting of exceptionally qualified administrative, research and technical personnel. This core staff should be supplemented by industry researchers, university faculty, federal laboratory researchers and graduate students.**

The MMC should have its own staff -- a core staff is needed to direct, coordinate and conduct research and educational programs conducted under the auspices of MMC. The staff should consist of administrators, research personnel and technicians/ equipment operators. The senior management requirements are discussed above.

Research teams should be organized around individual research projects. Each team should consist of a minimum of twelve people on a full-time equivalent basis:

- MMC Research Team Leader
- MMC Researchers (two)
- MMC Technicians (three)
- Industry Researchers (two - four)
- University Faculty (two - four)
- University Graduate Students (two - four).

It is imperative that the Research Team Leader have substantial experience in relevant technical areas. To the extent possible, and where appropriate, team members should represent a broad range of disciplines, e.g., chemistry, chemical engineering, electrical engineering, industrial engineering and solid state physics. Initially, MMC should establish three research teams. The focus of the individual teams should fit within a defined five- to ten-year research program.

Concerns were raised about the ability of the MMC to attract qualified personnel; it was felt that people may be unwilling to work for the MMC given the vagaries of public funding and its consortium structure. MMC will need to demonstrate firm multi-year funding commitments by industry and government prior to hiring staff. In addition, staff compensation has to be competitive, and may require a slight premium to offset perceptions of additional employment risk.

Industry researchers, university faculty and graduate students are likely to work at MMC on a part-time basis. University faculty can participate as consultants or adjunct faculty. Senior tenured faculty

are likely to participate on a consulting, rather than adjunct, basis. The form of participation will have to be negotiated with the particular university and individual. Graduate students could participate as part of thesis assignments or work coop programs. In addition, federal laboratory personnel could also be seconded to the MMC.

Most of the companies that we interviewed indicated that they would be willing to second staff to the Massachusetts Materials Center provided that it has an applied research orientation. This should be a requirement for major industrial sponsors. Companies should commit to sending personnel to the Center for minimum of three to six months per year. This commitment should be secured as soon as possible.

One area of concern raised by companies, universities and federal agencies is the position of MMC with respect to the participation of foreign graduate students and foreign companies. Some companies fear that foreign participation would defeat the purpose of the MMC -- to enhance the competitive position of U.S. firms. Defense agencies may want to limit the flow of technologies oversea as reflected in the Export Trade Act of 1984. Others do not see foreign participation as a major drawback and, in fact, feel that this would strengthen MMC by expanding the base of resources on which MMC can draw. This is clearly a difficult policy issue that needs to be thought out carefully by the MMC Operating Board, in consultation with legal counsel.

B. Facilities and Equipment

To fulfill its mission, and to attract and maintain the active involvement of participating universities and companies, as well as its own staff, the Massachusetts Materials Center must be fully equipped with state-of-the-art equipment.

Although MMC may have the option to build a new facility from the ground up, we recommend that Center acquire or lease existing facilities or, if possible, arrange for a building to be donated to the Center, and renovate to suit particular needs. This will result in lower initial capital costs; more importantly perhaps, it will allow MMC to become fully operational in a shorter period of time.

A total of approximately 50,000 square feet of space will be required initially for laboratories, offices and meeting rooms. This amount of space will permit some moderate expansion within the general context of electronic materials research. As MMC evolves, and embarks on new research efforts in different classes of materials, additional facilities will be required. We recommend that MMC should lease an additional 20,000 square feet to allow for expansion into areas outside of electronic materials. MMC should sublet available space until needed. In evaluating potential buildings, consideration should be given to the ability to expand further on-site or in nearby locations.

It is envisioned that the laboratory facilities for electronic materials will consist of four principal components:

A. Crystal growth, slicing, grinding, and polishing
B. Characterization of wafers
C. Preparation of active layers
D. Prototype fabrication

It should be noted that the prototype fabrication facility should not be limited to fabricating VLSI circuits based on silicon. Prototypes of different types of devices -- e.g., optical couplers -- based on different types of materials -- e.g., gallium arsenide -- will be developed and manufactured in the Center's facilities. This is broader than the planned microelectronics center foundry. Within the laboratories, equipment should represent the highest quality, state-of-the-art equipment available. It does not, however, need to accommodate high throughput given the research, rather than production, orientation of the facility. In some cases, a choice exists between two operations, as for example, between molecular beam epitaxy (MBE) and organometallic chemical vapor deposition (OMCVD). The final decision on equipment rests on decisions concerning the appropriate research emphasis of MMC. In this particular instance, we recommend that MMC acquire both types of equipment because of the uncertainty over which technique will emerge as preferable.

Figure 3 shows a general floor plan for the Massachusetts Materials Center. The total estimated space requirements for electronic materials are about 50,000 square feet. This includes approximately 25,000 square feet of laboratory space with clean rooms varying from A1000 to A10. Laboratories associated with each of these blocks should be grouped in blocks or modules. This will allow for the sequential flow of activities with additional space available for expansion. An additional 20,000 square feet should be secured to allow expansion into other areas or research. Table 3 lists the major functions and equipment contained in each of the labs, designated by a room or reference number on the floor plan.

MMC need not purchase all of the equipment listed, to the greatest extent possible, MMC should enter into suitable arrangements with universities, federal laboratories and private companies to secure access to needed equipment. For example, some of the analytical and characterization work should be contracted out to private analytical laboratories. These arrangements should not be restricted to Massachusetts institutions. For example, MMC could arrange to use the cold neutron research facility or the free electron laser at the National Bureau of Standards to investigate certain properties of materials.

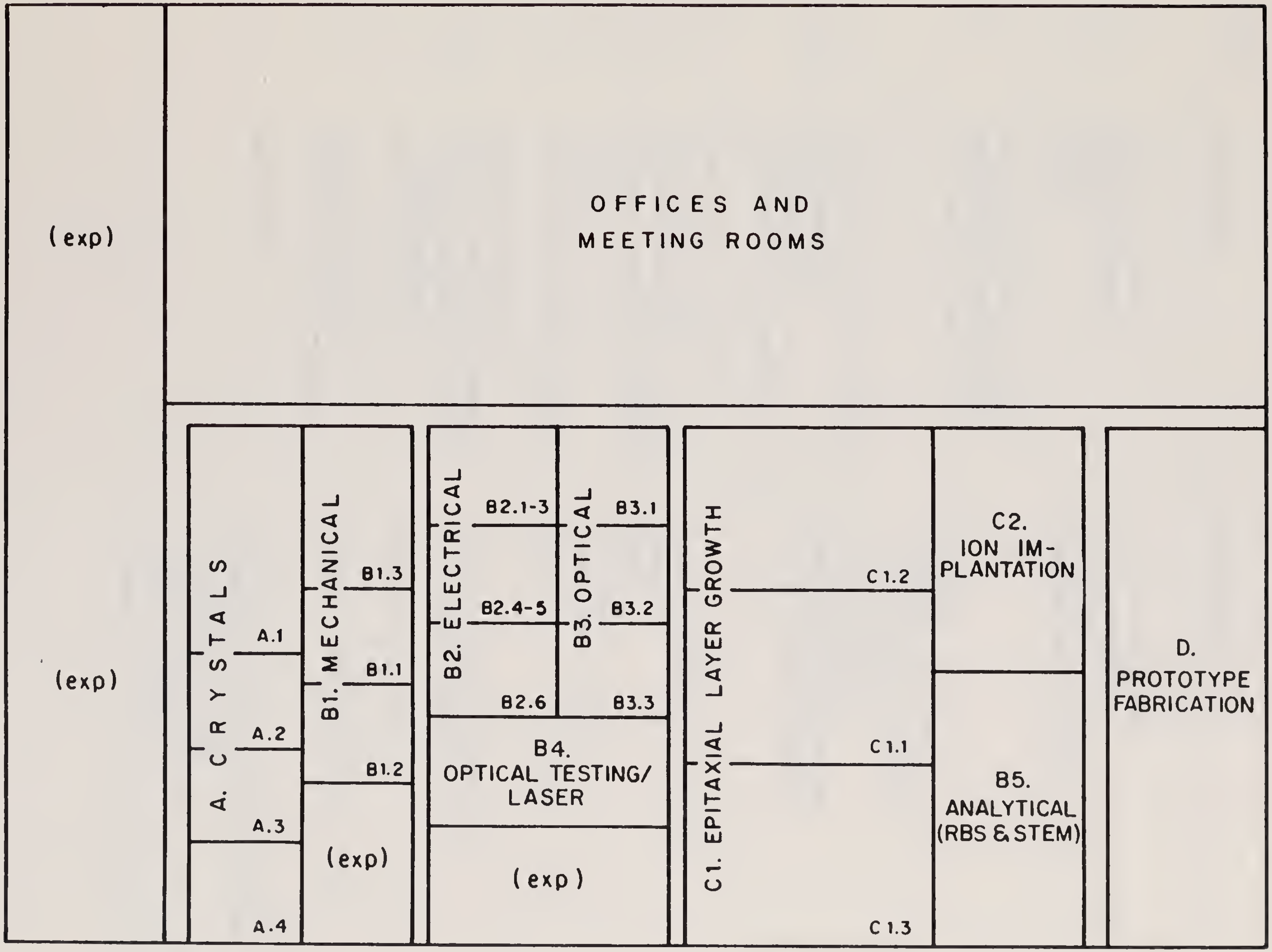

FIGURE 3 GENERAL FLOOR PLAN FOR THE MASSACHUSETTS MATERIALS CENTER

TABLE 3. DESCRIPTION OF MMC LABORATORY

ROOM NO.	FUNCTIONS	EQUIPMENT
A		
A.1	Grow crystals	Crystal pullers
A.2	Slice crystals	Slicers(saw)
A.3	Grind	Grinders
A.4	Polish	Mechanical polisher
B	Wafer Characterization	
B.1	Mechanical Properties	
B.1.1	Dislocation density	Furnace Chemical polisher Interference Contrast microscope
B.1.2	Flatness(Interferometry)	Interforemeter
B.1.4	Ellipsometry	Benchtop Ellipsometer
B.1.3	Orientation(X-ray)	X-ray Crystallography
	Available for expansion	
B.2	Electrical Properties	
B.2.1	Four-point probe	Misc. electronic & other
B.2.2	Van-der Pauw(resistivity)	same
B.2.3	Van-der Pauw(Hall-effect)	same
B.2.4	CV Plot	CV Plot
B.2.5	"Polaron" plotter	"Polaron" plotter
B.2.6	Deep level spectroscopy	DLTS
B.3	Optical Properties	
B.3.1	UV-VIS spectrophotometry	UV-VIS spectrophotometry
B.3.2	Fourier transform infrared spectroscopy	FTIR spectroscopy
B.3.3	Photoluminescence	Photoluminescence
B.4	Optical facility	Lasers, monochromators, etc.
	Available for expansion	
B.5	Analytical	Rutherford Back Scattering(RBS) Scanning Transmission Electron microscope(STEM) Phi Microprobe System (incl. Auger, ESCA, and SEM) Secondary Ion Mass Spectrometer(SIMS

TABLE 3. DESCRIPTION OF MMC LABORATORY

ROOM NO.	FUNCTIONS	EQUIPMENT
C	Prepare Active Layers	
C.1	Epitaxial layer growth	
C.1.1	Organometallic Chemical Vapor Deposition	OMCVD system
C.1.2	Molecular Beam Epitaxy	MBE
C.1.3	Chemical Vapor Deposition	CVD
C.2	Ion Implantation	MeV energy system
D	Pilot Processing Facilities	
D.1	Photolithography	Optical mask aligner Electron-beam lithography
D.2	Photoresist Placement and Development	Chemical hoods Spinner(photoresist) Bake(Photoresist)
D.3	Wet etching	Wet etch
D.4	Dry etching	Dry etch(plasma etching) Reactive Ion Etching
D.5	Metallization	Vacuum coater
D.6	Inspection	Microscopes, etc.

Structures at Cornell University in 1977, providing it with $2 million annually. In addition, NSF recently established an Engineering Research Center for Robotic Systems and Microelectronics at U.C. Santa Barbara with a grant of $14 million over five years. The ERC will focus on automated IC production. The NSF has also established the Engineering Research Center for Compound Semiconductor Microelectronics at the University of Illinois (Urbana). DOE is funding a new Advanced Materials Center at Lawrence-Berkley Laboratories. The $42 million facility will include equipment for research in electronic materials. The annual operating budget will be on the order of $3.5 million, less than a third will be earmarked for electronic materials. Brief profiles of selected university-based electronic materials programs are included in Appendix A.

Although there is a great deal of activity in electronic materials, efforts are fairly fragmented and largely focused on silicon. There is room for a new initiative in electronic materials, especially in non-silicon materials and materials processing.

C. Marketing Strategy

The MMC will have to be marketed to three distinct groups: industry, universities, and federal government.

- o Industry -- The Massachusetts Materials Center should actively seek industrial participation from material manufacturers, equipment manufacturers and end users of materials and components. Serious consideration should be given to not pursuing the concept any further without a clear commitment of funding and personnel from industry in Massachusetts.

- o Universities and Other Research Institutions -- Universities in Massachusetts have expressed interest in the basic MMC concept. MMC will need to identify and secure the up-front commitment of individual faculty members with expertise in electronic materials and with interest in participating in the MMC applied research and educational programs. In addition, MMC will need to establish suitable arrangements governing the nature and method of participation on an individual and institutional basis. MMC should emphasize the scale of research activities envisioned for the Center, the presence of sophisticated processing and characterization equipment, and the opportunity to work with industry on critical material and material processing problems.

MMC should have a two-tiered structure with two levels of corporate membership: sponsoring members and affiliate members. Sponsoring members, i.e, major contributors, would participate in a variety of ways:

- Representation on the Technical Advisory Committee
- Placements of company scientists and engineers at the Center
- Access to licensing opportunities resulting from MMC research
- Use of facilities and equipment
- Attendance at all MMC-sponsored conferences and seminars
- Subscription to all MMC publications.

Affiliate members would participate through:

- Use of facilities and equipment
- Attendance at all MMC-sponsored conferences and seminars
- Subscription to all MMC publications.

- Federal Government -- The federal government still has not focused on the critical importance of materials and materials processing. The government is now in the process of setting priorities and defining appropriate programs. The level of funding for materials research is on the order of $1.5 billion annually. The staff of the House Committee on Science and Technology estimates that the total amount of dollars going to research in electronic materials each year is no more than $250 million. Moreover, these monies are scattered among a number of federal agencies and across disciplines.

  The National Science Foundation has a number of programs that are relevant to the Massachusetts Materials Center. However, the general orientation of most programs is toward small grants, i.e., less than $100,000 per year. Funding, therefore, tends to be for labor and materials, not facilities and equipment. In most instances, facilities and equipment have to be in place prior to NSF funding. There are some exceptions. The NSF program offering the greatest promise for MMC is the Engineering Research Center. Begun

TABLE 5: PRO-FORMA STATEMENT OF REVENUES AND EXPENSES, ASSUMING FEDERAL GRANTS

($000 1987)

	Year Ending December 31,					
OPERATING REVENUES	1987	1988	1989	1990	1991	1992
Membership dues	$675.0	$1,370.0	$1,675.0	$2,020.0	$2,880.0	$3,200.0
Federal Operating Grant	0.0	5,000.0	5,000.0	5,000.0	5,000.0	5,000.0
Fees from Facility Rental	0.0	349.6	349.6	349.6	349.6	349.6
Fees for courses/seminars	0.0	52.0	104.0	104.0	104.0	104.0
Total Revenue	$675.0	$6,771.6	$7,128.6	$7,473.6	$8,333.6	$8,653.6
OPERATING EXPENSES						
Salaries and benefits	$105.6	$1,698.3	$2,101.9	$2,505.5	$2,505.5	$2,505.5
Travel	$6.0	$22.0	$26.0	$30.0	$30.0	$30.0
Facility rental	$0.0	$920.0	$920.0	$920.0	$920.0	$920.0
Office equipment & furnishings	$0.0	$50.4	$64.2	$78.0	$78.0	$78.0
Office supplies	$1.0	$9.5	$12.1	$14.8	$14.8	$14.8
Lab materials and supplies	$0.0	$100.0	$125.0	$150.0	$150.0	$150.0
Equipment service & maintenance	$0.0	$786.1	$786.1	$786.1	$786.1	$786.1
Additional utilities,user charges	$0.0	$198.0	$264.0	$330.0	$330.0	$330.0
Insurance	$0.2	$21.8	$22.6	$23.4	$23.4	$23.4
Legal and professional services	$37.5	$75.0	$75.0	$75.0	$75.0	$75.0
Journals and reference materials	$11.3	$20.0	$10.0	$10.0	$10.0	$10.0
Publications & communications	$2.5	$15.0	$20.0	$25.0	$25.0	$25.0
Miscellaneous	$0.0	$100.0	$110.0	$120.0	$120.0	$120.0
Total expenses	$164.0	$4,016.1	$4,536.9	$5,067.8	$5,067.8	$5,067.8
NET OPERATING REVENUE/SHORTFALL	$511.0	$2,755.5	$2,591.6	$2,405.8	$3,265.8	$3,585.8
CUMULATIVE REVENUE	$675.0	$7,446.6	$14,575.1	$22,048.7	$30,382.2	$39,035.8
CUMULATIVE OPERATING EXPENSES	$164.0	$4,180.1	$8,717.0	$13,784.8	$18,852.5	$23,920.3
CUMULATIVE NET OP.REV.(SHORTFALL)	$511.0	$3,266.4	$5,858.1	$8,263.9	$11,529.7	$15,115.5
CAPITAL ACCOUNTS						
CAPITAL OUTLAY	$0.0	($16,981.0)	$0.0	$0.0	$0.0	$0.0
RESERVE FUND	$0.0	$0.0	($2,884.0)	($2,884.0)	($2,884.0)	($2,884.0)
STATE CAPITAL GRANT	$675.0	$16,370.0	$2,955.0	$0.0	$0.0	$0.0
FEDERAL CAPITAL GRANT	$0.0	$10,000.0	$0.0	$0.0	$0.0	$0.0
CAPITAL BALANCE	$675.0	$9,389.0	$71.0	($2,884.0)	($2,884.0)	($2,884.0)
CUMULATIVE CAPITAL BALANCE LESS RESERVE FUND	$675.0	$10,064.0	$10,135.0	$7,251.0	$4,367.0	$1,483.0

TABLE 6. PROPOSED EQUIPMENT LIST FOR MASS. MATERIALS CENTER

Ref.	Description	Cost ($000)	Est. Life	Cost/ Year ($000)
A.1	Crystal Puller, Bridgeman	150	5	30.0
A.1	Crystal Puller, Czhokrowlsky	690	5	138.0
A.2	Slicers(saw)	100	7	14.3
A.3	Crystal grinder	125	7	17.9
A.4	Polisher, mechanical	80	7	11.4
B.1.1	Furnace, generic	1	7	0.1
B.1.1	Polisher, chemical	35	5	7.0
B.1.1	Interference Contrast Microscope	25	7	3.6
B.1.2	Interforemeter	15	7	2.1
B.1.3	X-ray crystallography	535	7	76.4
B.1.4	Ellipsometer, benchtop	10	7	1.4
B.2.1-3	Misc. electronic & other	60	5	12.0
B.2.4	CV plot	10	5	2.0
B.2.5	Polaron Plotter	65	5	13.0
B.2.6	Deep Level Trap Spectroscopy(DLTS)	25	5	5.0
B.3	UV-VIS Spectrosphotometry	45	7	6.4
B.3	FTIR	45	5	9.0
B.3	Photoluminescence	25	5	5.0
B.4	Optical facility lasers, monochromators, etc.	250	5	50.0
B.5	Rutherford Back Scattering	400	5	80.0
B.5	Scanning Transmission Electron Microscope (STEM)	450	5	90.0
B.5	Phi Microprobe System (incl. Auger, ESCA, and SEM)	700	5	140.0
B.5	Secondary Ion Mass Spectrometer	500	5	100.0
C.1.1	OMCVD System	600	5	120.0
C.1.2	MBE	750	5	150.0
C.1.3	CVD	200	5	40.0
C.2	Ion Implantation	800	5	160.0
D.1	Optical mask aligner	20	5	4.0
D.1	E beam lithography	1,600	5	320.0
D.2	Spin & bake & hoods	15	5	3.0
D.3	Wet etch	75	5	15.0
D.4	Dry etch (plasma & reactive ion)	375	5	75.0
D.5	Vacuum Coater for Metallization	75	5	15.0
D.6	Inspection microscopes, etc	25	7	3.6

TABLE 6. PROPOSED EQUIPMENT LIST FOR MASS. MATERIALS CENTER

Gen'l	Micropositioners	5	7	0.7
	Positioning systems, manual	5	5	1.0
	Positioning systems, automatic	10	5	2.0
	Wire bonder	15	5	3.0
	FET Tester	50	5	10.0
	RF Node Measurement System	30	5	6.0
	Dionized Water Supply System	50	7	7.1
	Liquid Nitrogen Distribution System	50	10	5.0
	Photomask cleaner	5	5	1.0
	Poisonous gas scrubbers	200	7	28.6
	Dry boxes	5	7	0.7
	Clean hoods	75	7	10.7
	Ultrasonic cleaners	10	7	1.4
	Gas handling systems	25	7	3.6
	Vacuum service	25	7	3.6
	Furnaces	15	7	2.1
	Scriber	15	5	3.0
	Dicer	15	5	3.0
	Clean rooms	7,500	7	1,071.4
		-------		-------
	Total	$16,981		$2,884

Center would employ roughly 40 people directly by year four and support 16 full-time equivalent faculty and graduate students. Participating industry research scientists should be supported by their companies. Most of these people will be involved in research on electronic materials. To be competitive, MMC will have to offer salaries in the range of $120,000 for the CEO, $100,000 for the VP Research, $80,000 for the VP Administration, $70,000 for Research Team Leaders, $36,000 for Research scientists, and $25,000 for technicians.

- Facility Rental. Space costs are the next largest budget item, accounting for an estimated $920,000 per year. This estimate is based on costs quoted for office and lab space in the Routes 128/495 belt of $22 and $12 per square foot, respectively. It includes 20,000 square feet for offices and meeting rooms, 25,000 square feet for labs (including corridors), 5000 square feet of storage or unfinished space. An additional 20,000 square feet is included to enable expansion into new research areas. For the first five years of operation, we have assumed that MMC will be able to recover half the costs of this expansion space by subletting.

- Equipment Service and Maintenance. Service contracts valued at 7.5 percent of the capital cost of the lab equipment, and one percent of clean room costs, add about $790,000 to the budget each year.

- Additional Utilities and User Charges. This expense item consists of computer user charges and utilities, primarily electricity. It is recommended that the Massachusetts Materials Center purchase micro-computers for the researchers, but buy mainframe time from universities in the area. We have assumed that each group will use 80 hours of cpu time annually at a cost of $200/cpu hour. Utility costs are estimated to increase from $3 to $5 per square foot as activity levels increase.

- Laboratory Materials and Supplies. These chemical materials and gases are estimated to increase from $100,000 in year two and grow by $25,000 per year as research activities expand.

- Other Operating Expenses. For office equipment and furnishings, we have assumed that such equipment will be leased or financed. The major item is the engineering work stations, two of which are allocated to each group. Personal computers are included for each management staff person, plus one for each research group. Travel and office

supplies are directly related to the number of staff members. Legal and professional services are estimated to cost $75,000 annually. The budget also covers the costs for development of a library and use of on-line literature search services, and publications of newsletters and research papers.

As MMC expands into new research programs, i.e., outside of electronic materials, most costs will increase in rough proportion to the additional staff.

B. Revenues

The pro-forma statements in Tables 4 and 5 include operating revenue derived from four different sources. Three of these sources -- corporate membership dues, facility rental, and courses/seminars -- appear on both statements. The fourth source of operating revenue -- federal operating grants -- appears only in Table 3.

- o Membership Dues. We have estimated industrial support as a function of the two-tiered membership structure discussed in Section VI.C. Sponsoring members of the MMC are estimated to increase from five to ten over the six-year period. Annual membership fees for this group are estimated at $250,000 per firm. In addition, firms joining MMC as sponsoring members after year one would be required to pay an additional amount the year they join. This fee is set as a percentage (increasing over time from 10 to 50 percent) of membership fees they would have paid since year one of operation. Membership income also includes dues from affiliate members, a group expected to grow from 10 in year one to 20 by year six. Annual dues for this group are estimated at $10,000 with no recapture of foregone dues. Dues are expected to grow from $1.7 million in the first year of full operation to $3.2 million in 1992.

- o Equipment Rental. This revenue includes income from the rental of MMC equipment and facilities for proprietary corporate research. The capacity available for these activities has been estimated at 10 percent of total hours available annually (2400). We have assumed that corporate research activities will use half of this available capacity (120 hours annually). Fees for equipment and facility rental were set at 300 percent of the hourly annualized cost.

- o Fees from Courses and Seminars. This revenue reflects an annual program of MMC-sponsored professional conferences and seminars. These include one major conference annually, attended by 200 people at $500 each, and four seminars annually (one per quarter), attended by 20 people at $50 each.

- o Federal Operating Grant. This revenue line appears only in Table 3. It reflects a large federal operating grant such as the one currently under consideration by DARPA.

C. Capital Funding

We have projected the expenditure of $17 million in 1988 for the purchase of laboratory facilities and equipment. In addition, the pro-forma statements include the funding of a capital reserve account for the purchase of new equipment in future years. Annual payments into this fund equal the annualized cost of the initial capital outlay for equipment and facilities.

The annual state capital grant is equal to revenues from membership dues, federal operating grants, and federal capital grants (cash and/or value of donated building.) This amount reflects the dollar for dollar matching grant of $20 million stipulated in existing legislation.

A federal capital grant of $10 million assumes a successful bid on a project of the scale envisioned by DARPA. Alternatively, this amount conservatively reflects the value of a building donated to the MMC.

D. Analysis

As shown in Table 4, in the absence of additional grants to cover operating cost, MMC will suffer a significant shortfall in net operating revenue in every year. The cumulative net operating deficit is estimated to total $10 million by the end of 1992.

It is our understanding that the $20 million appropriated by the state may be used only for facilities and equipment. It may not be used to cover the operating deficits. Given the structure of the required match, and the projected level of industry support, MMC will not be able to cover the estimated initial capital outlay in 1988. Industrial funds will only trigger the release of less than $1.4 million form the State. As a result, $15.6 million needed for facilities and equipment will remain unfunded. Morevoer, only $11 million of the total $20 million available will be released to MMC by 1992. These monies will flow to MMC at the rate of $1 - 3 million annually. Although the annual state capital grants in subsequent years will roughly cover requisite payments into the capital reserve fund, initial capital needs will remain unmet.

Additional operating and capital support will be required to ensure the financial viability of MMC. As shown in Table 5, if MMC succeeds in securing an initial capital grant of $10 million and annual operating grants of $5 million, from sources other than the state, the Center will be financially viable. These additional grants will accelerate the release of state monies and will be more than

sufficient to cover operating and capital needs. In fact, at this level of funding, MMC would be in a position to expand operations in terms of staff and equipment into additional areas. In this way, electronic materials (particularly opto-electronics) can be used as a base on which to build a larger and broader material center.

IX. IMPLEMENTATION PLAN

There are a number of steps that MTPC should take to establish the Massachusetts Materials Center:

1. Reach a decision on whether or not to proceed with the Massachusetts Materials Center -- The MTPC Board needs to discuss the merits of the proposal and decide quickly on whether or not it wants to pursue the idea any further. More than two years have passed since the initial concept for the MMC was formulated. A large number of companies, universities and government agencies have been involved in the process; representatives from these organizations are expecting a decision. Moreover, the potential for securing DARPA funding presents an opportunity that needs to be pursued as rapidly as possible. Other areas of the country will be quick to act, leaving Massachusetts in their wake.

2. Appoint a staff person or retain outside assistance to take lead responsibility for establishing the Center -- If the decision to proceed is affirmative, an *ad hoc* process will not be enough. The next steps in the process of establishing the Center will require a great deal of time and effort. Someone needs to take the lead in marshalling the various resources required to effect the business plan. At this stage, it is too early to hire full-time staff. MTPC will need to rely on existing staff or retain outside assistance.

3. Establish a core group of senior university and industry representatives who are committed to the establishment of the Massachusetts Materials Center -- Before going any further, MTPC needs to secure the commitment of a small group of senior people from industry and universities. These individuals will form the nucleus around which the Center can be built. This commitment needs to be expressed in time and money. Companies should be required to sign a letter of intent with payments contingent upon successful funding, and contribute to $10,000 to $20,000 in "earnest money" that can be used to pursue the concept further.

4. Draft by-laws and research plan -- The core group should take responsibility for drafting the by-laws of the Massachusetts Materials Center. This should be done in consultation with legal counsel and with various legislation in mind, e.g, the National Cooperative Research Act of 1984. (See Appendix D). The core group should also draft a specific research program, including the first year research plan and budget.

5. Establish the Massachusetts Materials Center as a formal organization -- This step is required to begin soliciting industrial contributions and secure subsequent state funding on a matching basis. The legal structure needs to reflect both the existing state legislation, and the needs of corporations and universities as reflected in the by-laws of the Massachusetts Materials Center. At this time, the Operating Board of MMC should be appointed.

6. Begin search for management staff -- MMC Operating Board should initiate a search for the CEO, Vice President for Administration, and Vice President for Research.

7. Initiate discussions with the Defense Sciences Office of DARPA -- The core group and staff person should approach DARPA as soon as possible. It may be appropriate to send a copy of the Massachusetts Materials Center Business Plan to Dr. Richard Reynolds, Director, Defense Sciences Office on a confidential basis. DARPA has already established contacts with university and industrial representatives across the country. MMC needs to get into this loop -- time is of the essence.

8. Initiate discussions with representatives of NSF Engineering Research Center program and with the DOD/University Research Initiative program -- The next funding cycle for Engineering Research Centers begins in September 1987 when the next round of proposals are due. The core group and staff person should discuss the potential for funding with an appropriate NSF representative. Given the relatively short lead time, this should be done as quickly as possible. Pending the results of these discussions, a proposal to NSF should be prepared. Discussions should also be held with DOD on the potential for securing funding under the University Research Initiative Program.

9. Identify and investigate alternative courses, if funding from DARPA and NSF appears unlikely -- It may be possible that MMC will be able to secure neither DARPA nor NSF funding. If that situation arises, MTPC will either have to make a decision not to proceed further or launch out on an alternative course of action. MTPC will probably be in a good position to make this decision by the end of 1987. However, MTPC should begin to lay out possible contingencies over the next few months, e.g., accelerating State match, and financing with state guarantees.

10. Hire management staff -- If the discussions hold promise, the MMC Operating Board should select and hire management staff.

11. Begin broader marketing efforts targeted to companies within Massachusetts and outside of the State -- The staff should prepare a prospectus and brochure to be used in marketing efforts. A list of potential sponsors and responsible individuals should be assembled. Marketing should begin with firms in Massachusetts through personal visits to potential sponsors. These contacts should be made by the staff person and core group. In addition, telephone calls and limited follow-up visits should be made to companies outside of the State. MMC should sponsor public meetings at this time as part of a promotion and public awareness program.

12. Identify building that meets criteria -- A preliminary search for an appropriate building should be conducted. This search should focus on buildings that could be donated by the federal government or private industry.

13. Acquire building, equipment and staff, and begin operations -- When funds have been secured from industry, and the federal and state governments, MMC will be in a position to initiate full operations.

APPENDIX A

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS
ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
Alfred University Institute for Electronic Ceramics Alfred, NY	Research and development of high frequency magnetic ceramics.		Established as part of a major commitment to the development of millimeter wave length ferrite materials.	The initial goal is to establish the first major research center on high frequency magnetic materials in the U.S.		
Georgia Institute of Technology Microelectronics Research Center Atlanta, GA	Compound semiconductor materials research, semiconductor device research, microfabrication of low voltage field emitter array cathodes, ion implantation and surface analysis, materials and device characterization, device physics.	1982	Facilitation of the further development of a comprehensive microelectronics research and development program of national stature within existing Georgia Tech academic and research units.	Parent institution, U.S. Government, industry State: $15 mil. capital fund -- 2/3 for new building and 1/3 for equipment; Georgia Tech will match $15 mil. through nonstate sources over a 5-year period.	35-40 professional level personnel	Broad array of analytical instrumentation including scanning electron microscopes, a transmission electron microscope, x-ray crystallography facilities, and metallurgical, chemical and ceramics lab facilities.
Massachusetts Institute of Technology Materials Processing Center (MPC) Cambridge, MA	Materials processing, engineering, and economic studies in ferrous and nonferrous metals, ceramics, polymers, electronic materials, composites, rapid solidification, welding/joining, electroprocessing and mathematical and physical modeling.	1979	To establish research base in materials processing and to serve as a conduit to promote ties with industry.	$300,000 grant initially from NASA. FY 1986, received 6,579,603 - 42.5% from industry, 57.5% from federal govt.	62 research professionals 86 supporting professionals 5 technicians 8 others 25 visiting scholars	Maintains 3 research consortia, the ceramics processing laboratory, the materials system laboratory, and the mathematical modeling laboratory.

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS (Continued)

ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
Rutgers University The Center for Ceramic Research Piscataway, NJ	Ceramic processing and its impact on improved properties and reliability of technically important classes of materials. Studies in special material classes and properties focus on electronic ceramics, structural ceramics and ceramic films and coatings.	1982	To do generic, basic research on ceramics in areas of interest to its members. To stimulate technological and commercial development in ceramics, especially by member organizations.	Parent Institution; NSF funds (5 yr. grant of $710,000 in 1982) State funds ($9,000,000 building grant, 1984) industrial affiliates (30 which each pay $35,000/year). Annual support for salary and supplies, $931,000.	15 research professionals 3 supporting professionals 5 technicians 5 others	55,000 sq. ft. building; equipment for material preparation and handling, powder characterization, ceramic processing, chemistry and phase characterization, surface chemistry characterization, microstructure characterization, optical characterization, electrical characterization, and mechanical characterization.
Stanford University Materials Research Laboratory Palo Alto, CA	Optoelectronic and infrared materials; polymers; structure and properties of thin films; photon materials research; x-ray materials research.			NSF in FY 1986: 2,995,000		
University of Alabama in Huntsville, Center for Applied Optics Huntsville, AL	Holography, coherent optics, optical coatings, spectroscopy, fiber optic; lasers, lens and system design, electro-optical systems, image processing, radiometry and infrared technology and detectors.	1985		Parent institution federal and state governments Volume of research in 1986: $4 million 1987: $6 million	15 research professionals 4 supporting professionals 1 technician 5 clerical workers 1 visiting scholar	

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS (Continued)

ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
National Bureau of Standards Institute for Materials Science and Engineering Washington, DC	Metals, ceramics, composites, polymers; involve interrelationships between materials processing, structure, properties and performance.		Serves industry, government agencies, and the general scientific and engineering community through the provision of critical data, concepts, measurement methods and standards necessary for the synthesis, processing and efficient use of materials.	In 1985, $33 million from direct appropriations and contracts from other federal agencies.	400	Chemical synthesis laboratories; metallurgical processing laboratory; polymer processing; thin film laboratory; nuclear reactor facility; quantitative x-ray diffraction laboratory; quantitative microscopy; and advanced NDE laboratories.
Penn State University Materials Research Laboratory University Park, PA	Material science, specializing in nonmetalics and ceramics including crystal prep, synthesis and growth, elastic and electrical properties of polycrystalline systems; onic solids; and NSF and MRG chemically bonded ceramics.	1962		Parent Institution Federal, State Local governments 1986 volume of research: $6 million	40 research professionals 30 postdoctoral fellows, 12 technicians, 80 others, 20 industry	For a special high pressure, high temperature synthesis and visiting scholars instrumental analysis of solids.
Princeton University Department of Electrical Engineering, Electronic Materials and Devices Programs Princeton, NJ	Semiconductor and insulator physics, electronic properties of 2-D systems, solid-state interactions at semiconductor interfaces, radiation damage.		Program directed toward preparing student for research, advanced development or teaching in areas of solid state electronics, physical electronics, electronic materials or the physical aspects of electrotechnology.		6 research professionals 8 supporting professionals 9 technicians 2 others	Rare-earth ion exchange separation facility, electron-beam melting and arc casting equipment, and distillation and sublimation facilities.

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS (Continued)

ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
University of Illinois at Urbana-Champaign, The Center for Microanalysis of Materials Research Laboratory Urbana, IL	Analysis of complex materials (metals, ceramics, polymers, and semiconductors) and their properties (optical, mechanical, electronic and magnetic).			Mostly self supporting U.S. Department Energy NSF	53 research professionals 4 technicians 57 students 6 visiting scholars	47,500 sq. ft. (occupancy 1987) 82,000 sq. ft. building (1986 ground breaking)
University of Texas at Austin Center for Research in Materials Science and Engineering Austin, TX	Microstructure properties of metal, ceramic, polymer, electronic, composite and biomedical materials. Programs in electronic materials, ion implantation, x-ray crystallography, optical materials and biomaterials, solid state reaction kinetics.	1982	Materials Science and Engineering research.	Parent institution U.S. Government Industry 1986 volume of research: $125,000 1987: $150,000 1988: $175,000	30 research professionals 4 technicians 3 others 80 graduate students 10 visiting scholars	X-ray diffraction, optical metallographies, and ultra high vacuuming; mechanical testing equipment

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS (Continued)

ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
University of California Lawrence Berkeley Laboratory Center for Advanced Materials Berkeley, CA	Catalysis, instrumentation and sensors, polymers and polymer composites, ceramic/metal interfaces, light alloys and electronic materials.	1983	To perform high quality materials research direction to the long range needs of high technology, energy-related U.S. industries. To offer education and training opportunities to scientists and engineers specializing in materials related disciplines. To explore new methods for cooperation and technology transfer between a federal lab and industry to accelerate translation of science into new technology.	U.S. Government Industry FY 1984 $2,800,000		
University of California, Santa Barbara Center for Robotic Systems in Microelectronics (CRSM) Santa Barbara, CA	Robotic system engineering and automated microelectronics manufacturing. Research objective is to create new technologies in flexible automation for semiconductor devices fabrication, and to educate a new generation of engineers skilled in the implementation of robotic systems.	1985	Applied and basic research.	Federal grants, industry, parent institution.	3 directors 38 research professionals 12 faculty researchers 6 supporting professionals	

PROFILES OF SELECTED MATERIALS SCIENCES RESEARCH CENTERS (Continued)

ELECTRONIC MATERIALS

Name/Location	Research Initiative	Date Founded	Program Mission/Activities	Funding Levels/Sources	Faculty/Staff	Facilities/Equipment
University of Arizona Optical Services Center (OSC) Tucson, AZ	Optical science and engineering, including large telescope design, large mirror fabrication, optical instrumentation, quantum electronics, image reconstruction and enhancement, computer-aided pattern recognition, optical materials, thin film technology, integrated optics and medical imaging devices.	1966	Optical science research and optical engineering.	Parent institution, U.S. government, industry.	40 research professionals 100 supporting professionals 30 technicians 20 others 15 visiting scholars	
University of Arizona, Tucson Optical Circuitry Cooperative Tucson, AZ	Responsive to research suggestions of industrial advisory board. Initial areas are growth and characterization of optical materials, non-linear optical device concepts, optical signal processing systems and theoretical foundations.		Perform research to provide a data base to allow the development of optical circuitry devices.	NSF State of Arizona Member companies ($50,000 each/year)	16 research professionals 10 graduate students 5 postdoctoral fellows	

APPENDIX B

NATIONAL SCIENCE FOUNDATION

Program Announcement

ENGINEERING RESEARCH CENTERS

(Centers for Cross-Disciplinary Research in Engineering)

The Directorate for Engineering will continue the Engineering Research Centers program started in Fiscal Year 1985. The goal of the Centers program is to develop fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and prepare engineers to contribute through better engineering practice. Engineering education and research are key elements in improving U.S. industrial productivity, and they must be firmly linked in the Centers. The Centers will be supported to meet a need for providing cross-disciplinary research opportunities for faculty and students, for providing fundamental knowledge which can contribute to the solution of important national problems, and for preparing engineering graduates with the diversity and quality of education needed by U.S. industry.

While the Centers will differ from one another, they should all share four defining characteristics: First, they should provide for working relations between students and faculty on the one hand, and practicing engineers and scientists on the other. Second, their programs should emphasize the synthesis of engineering knowledge; they should seek to integrate different disciplines in order to bring together the requisite knowledge, methodologies, and tools to solve issues important to engineering practitioners. Third, the programs must contribute to the increased effectiveness of all levels of engineering education. Fourth, the Centers should have a strong commitment from industry (money, equipment, and people) to assure its involvement in the research and educational aspects of the Centers; and, where appropriate, share a similar commitment of support from state or local governments.

The Centers are to be located at academic research institutions where they are expected to promote strong links between research and education. Cooperation between one or more schools in a region is encouraged where the combined activity will enhance the Center and the engineering education and research activities of the region.

Each Center should focus on a particular area of both industrial and national importance where development of fundamental engineering knowledge will enhance international competitiveness and is a major technological concern. The proposing institution should identify the subject area and focus of its proposed Center, as well as the approach it considers best to address the area in accordance with the interests and capabilities of the campus and affiliated institutions.

A Center is expected to possess the following features:

- Provide research opportunities to develop fundamental engineering knowledge in areas critical to U.S. competitiveness where team efforts of individuals from various backgrounds, possessing different engineering and scientific skills, will contribute more to the research and goals of the Center than would occur with individual research grants. The nature of the Center's research should be cross-disciplinary.
- Emphasize in its research and education programs the synthesis, integration, and management of engineering systems, as well as ethical and values issues, as appropriate.
- Provide experimental capabilities not available to individual investigators because of large instrumentation acquisition costs, requirements for a large number of skilled technicians, or other maintenance and operating requirements.
- Include in the Center the participation of engineers and scientists from industrial organizations in order to focus the activities on current and projected industry needs and enhance the education of students in the systems aspects of engineering (i.e., engineering design, reliability, and economic factors). State and local agencies or government laboratories involved in engineering practice may also be participants.
- Include a significant education component involving both undergraduate and graduate students in the Center research activities, since such participation would expose future engineers to the systems aspects of many engineering fields and better prepare them for engineering practice.

Programs described in this announcement are in Category 47.041 (Engineering Science) of the "Catalog of Federal Domestic Assistance."

- Develop new methods for the timely and successful transfer of knowledge to industrial users and, as appropriate, codification of new knowledge generated at the Center and continuing education of practicing engineers.
- Strive to involve a significant number of its home institution's graduate engineering students at both the master's and doctoral levels. The Center's program should also have a substantial impact on undergraduate engineering students. A minimum faculty commitment of three full-time equivalent (FTE) positions is probably essential. It is anticipated that faculty staffing will be supplemented by engineers provided by industry.

Who May Submit

U.S. academic institutions with engineering research and education programs are invited to submit proposals. Proposals involving multi-institutional arrangements between engineering colleges and other schools in the region also are eligible.

The Foundation welcomes proposals on behalf of all qualified engineers and scientists. NSF strongly encourages women, minorities, and the physically handicapped to participate fully in the program described in this announcement, both as investigators and as students.

Principal Investigator

The individual designated as principal investigator will be responsible for management and staffing; procurement, use, and maintenance of equipment; and the research funds for the Center.

Deadlines

Proposals are due September 15, 1986. Awards are planned for the following May.

Evaluation of Proposals

Proposals will be evaluated in several stages, which may include panel review, site visits, and NSF review. Proposals may be declined at any point in the review process following the initial peer review.

Criteria used in the evaluation of proposals are described in the NSF document *Grants for Research and Education in Science and Engineering* (NSF 83-57). The four equally rated criteria are:

1. *Research Performance Competence*—(a) Technical competence of the proposed team, technical soundness of the proposed approach, and the adequacy of the institutional and other available resources; and, (b) Likelihood that the management plan will be effective in organizing human and physical resources and provide an ongoing synergistic focus on engineering systems enhancing international competitiveness.
2. *Intrinsic Merit of the Research*—Likelihood that the research will be innovative and lead to new discoveries or fundamental advances within engineering; and, the likelihood that the research of the cross-disciplinary academic team, stimulated by the industrial participants, will increase the merit of the research and have greater impact than the sum of individual projects.
3. *Utility or Relevance of the Research*—Likelihood that the research will serve as a basis for new or improved technology, the importance of the research to U.S. international competitiveness, and its relevance to national technological problems.
4. *Effect of the Research on the Infrastructure of Science and Engineering*—Likelihood that the research will improve the scientific and engineering enterprise and its education activities in ways other than those encompassed by the above criteria, including: stimulation of quality research in underdeveloped engineering fields important to both international competitiveness and national technological problems; distribution of resources with respect to institutions and geographical area; and improved and timely dissemination of research results.

Awards

Awards will be made as continuing cooperative agreements for an initial duration of five years. The first year budget for each Center will be for start-up. Once fully developed, each Center's NSF operating budget will depend upon the needs, plans, and performance of the Center, as well as the availability of funds. The actual number of Centers funded in each year will depend on the merit and responsiveness of the proposals received and the funds available.

Centers and affiliated programs will be reviewed for funding by a hierarchy of peer review panels chosen by NSF. The progress and plans of each funded Center will be assessed annually. During the third year of operation, the Centers will be reviewed by NSF and some of the initial reviewers. The review will determine if the Center is meeting the goals and objectives proposed, including the quality of research and the extent of industrial participation, and will be used to determine whether NSF will continue to support the Center fully for the remaining two years, or will provide decreased funding to terminate the Center at the end of the cooperative agreement. It is anticipated that successful Centers may be funded beyond the initial five-year period, subject to satisfactory peer review.

Support of the Engineering Research Centers program is contingent upon the availability of funds for this purpose. This announcement does not obligate NSF to make any awards if such funding is not available.

Proposal Format

The proposal should be prepared following the guidelines contained in the NSF document *Grants for Research and Education in Science and Engineering* (NSF 83-57) and the instructions which follow in this announcement.

Each proposal should reflect the unique combination of the proposing institution's interests and capabilities and should discuss the features of the proposed Center in sufficient detail to be evaluated in accordance with the criteria listed in this announcement. In order to facilitate review, the proposals should contain only material essential for the review. Since reviewers will be asked to review more than one proposal, lengthy proposals are not recommended. Proposals should be securely fastened together but not placed in ring binders. The cover letter for the proposal should grant, or deny, permission to NSF to include the institution name, proposal title, name of the principal investigator and telephone number in a list to be made available by NSF to qualified industrial requests. Each proposal should contain the following:

1. *NSF Cover Page* (NSF 83-57 Appendix II).
2. *Supplementary Information*—Principal Investigator(s) Center/Project Director(s). NSF Form 1225 (NSF 83-57 Appendix III). Attach one copy to the signed copy of the proposal. Do not include the form within the body of the proposal, this will compromise the confidentiality of the information.
3. *Table of Contents* with page numbers keyed to the major sections of the proposal.
4. *Executive Summary* of no more than three pages which provides a brief description of the proposed Center and its features.
5. *Rationale for the Center* and its importance to international competitiveness or a major national concern.
6. *Description of the Research* included in the focus of the Center, and the major thrusts of the research. Describe the key technical problems blocking advances in the area and the proposed research plan for dealing with these issues and leading to their successful resolution. This section should be no more than 20 single-spaced pages.
7. *Educational Features* of the proposed Center, including means to be used to emphasize the systems aspects of engineering and to train students in synthesizing, integrating and managing engineering systems.
8. *Facilities for the Center*, including a description of the available facilities and/or any plans for new or renovated space and the estimated costs.
9. *Management Plan*, including the organizational structure of the Center, mechanisms for focusing Center activities and selecting related research projects, allocation of funds and equipment, information on faculty promotion and tenure practices for faculty members involved in cross-disciplinary research, and university plans for the Center, including self-evaluation. This section should also include an organizational chart for the Center and plans for industrial participation, support, and interaction.
10. *Information Dissemination*. Methods for transfer of knowledge to users and the codification of new knowledge generated at the Center.
11. *Institutional and Industrial Support* for the Center, including a description of anticipated support and firm commitments: money, equipment, facilities, and personnel from all sources. This section should also include a summary for each year in tabular form.
12. *Budget*. A proposed five-year budget for funds requested from NSF comprised of separate annual budgets for each year (NSF Form 1030 in Appendix IV, NSF 83-57). Budget estimates for equipment items exceeding $1,000 each and construction of new buildings for the Center, up to 25% of costs or $250,000, whichever is smaller, should be indicated in Block D of the form and should be described and justified separately.

    The total amount requested from NSF for the five-year period should be shown on the cover page of the proposal.

    Appendices. Include the following items:

    1. *Center Participants*. A list should be prepared of the individuals who are key to the Center and other participating individuals. The list should identify departmental (or industrial) affiliation and discipline. **Its location in the proposal should be indicated in the Table of Contents.**

        Biographical information (limited to two pages per individual) on the principal investigator and all faculty members or other individuals from affiliated institutions who will be directly involved in the formation, development, or use of the Center. The list of publications for these individuals should be limited to the ten most relevant.

    2. *Current and Pending Support* (NSF 83-57 Appendix VI) for key individuals with academic affiliations requesting salary support from NSF.

Where and How to Submit Proposals

Twenty copies of the proposal should be submitted to:

Data Support Services Section
Attn: Engineering Research Centers Program
National Science Foundation
Washington, D.C. 20550

One copy of the proposal must be signed by the principal

investigator (proposed Center Director) and an official authorized to commit the institution in business and government affairs.

Additional Information

Copies of *Grants for Research and Education in Science and Engineering* (NSF 83-57) are available at no cost from:

Publications Unit, Room 233
National Science Foundation
Washington, D.C. 20550

For inquiries, contact the Division of Cross-Disciplinary Research (202-357-9707).

The Foundation provides awards for research in the sciences and engineering. The awardee is wholly responsible for the conduct of such research and preparation of the results for publication. The Foundation, therefore, does not assume responsibility for such findings or their interpretation.

The Foundation welcomes proposals on behalf of all qualified scientists and engineers, and strongly encourages women, minorities, and handicapped to compete fully in any of the research and research-related programs described in this document.

In accordance with Federal statutes and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or physical handicap shall be excluded from participation in, denied the benefits, or be subject to discrimination under any program or activity receiving financial assistance from the National Science Foundation.

The National Science Foundation has TDD (Telephonic Device for the Deaf) capability which enables individuals with hearing impairment to communicate with the Division of Personnel and Management for information relating to NSF programs, employment, or general information. This number is (202) 357-7492.

APPENDIX C

APPENDIX C

SUPPORTING ASSUMPTIONS

	Year Ending December 31,					
INCOME	1987	1988	1989	1990	1991	1992
Membership dues	675	1370	1675	2020	2880	3200
Major Corporate	5	5	6	7	9	10
10->15 by '92 @250/yr + recap	625.0	1,250.0	1,525.0	1,850.0	2,700.0	3,000.0
Minor Corporate	10	12	15	17	18	20
10->20 by '92 @10/yr, no recap	50.0	120.0	150.0	170.0	180.0	200.0
Fees for courses/seminars	104.0	104.0	104.0	104.0	104.0	104.0
1 major/yr;200 persons@$500per	100.0	100.0	100.0	100.0	100.0	100.0
1 sem/qtr;20 persons@50/per	4.0	4.0	4.0	4.0	4.0	4.0
Fees from use of equip. & fac.	0.0	349.6	349.6	349.6	349.6	349.6
5% of 240 days @10 hrs per;	0.0	120.0	120.0	120.0	120.0	120.0
ann'l equip cost/2400 hrs;	0	0.971	0.971	0.971	0.971	0.971
markup = 300%	0.0	3.0	3.0	3.0	3.0	3.0
STATE CAPITAL GRANT						
FOR 1ST:upto $20mm @ $/$Ind	675	1370	1675	2020	2880	3200
sum of ind to date	0	675	2045	3720	5740	8620
FOR 2ND:upto $20mm @ $/$ind&fed	675	16370	2955	0		
sum of ind. & fed. to date	0	675	17045	20000	20000	20000
FEDERAL CAPITAL GRANT	0	10000				
FEDERAL OPERATING GRANT						
-- NSF	0	5000	5000	5000	5000	5000
-- DARPA	0	5000	5000	5000	5000	5000

			Year Ending December 31,			
EXPENSES	1987	1988	1989	1990	1991	1992
SALARIES AND BENEFITS	105.6	1,698.3	2,101.9	2,505.5	2,505.5	2,505.5
Management						
Executive Director	30.0	120.0	120.0	120.0	120.0	120.0
VP, Finance and Administration	20.0	80.0	80.0	80.0	80.0	80.0
VP, Research	25.0	100.0	100.0	100.0	100.0	100.0
Office support staff	6.3	75.0	75.0	75.0	75.0	75.0
Subtotal	81.3	375.0	375.0	375.0	375.0	375.0
Benefits @ 30%	24.4	112.5	112.5	112.5	112.5	112.5
Total, management	105.6	487.5	487.5	487.5	487.5	487.5
Program Groups: # groups	0	3	4	5	5	5
Group Leaders	0.0	210.0	280.0	350.0	350.0	350.0
Research Scientists	0.0	216.0	288.0	360.0	360.0	360.0
Technical Support	0.0	225.0	300.0	375.0	375.0	375.0
Office support	0.0	30.0	40.0	50.0	50.0	50.0
Benefits for MMC staff	0.0	204.3	272.4	340.5	340.5	340.5
Industry research scientists	0.0	0.0	0.0	0.0	0.0	0.0
Adjunct faculty	0.0	175.5	234.0	292.5	292.5	292.5
Graduate student assistants	0.0	150.0	200.0	250.0	250.0	250.0
Total, program groups	0.0	1,210.8	1,614.4	2,018.0	2,018.0	2,018.0
# MMC employees	4	26	32.5	39	39	39
# FTE industry, faculty, students	0	12	16	20	20	20
TRAVEL (@ $1,000/trip)	6.0	22.0	26.0	30.0	30.0	30.0
8 trips/yr for exec dir	4	8	8	8	8	8
2 trips/yr for @ grp ldr & res vp	2	8	10	12	12	12
1 trip/yr for @ staff scientist	0	6	8	10	10	10
FACILITY RENTAL	0.0	920.0	920.0	920.0	920.0	920.0
Office: 20,000 sf	0.0	440.0	440.0	440.0	440.0	440.0
Labs: 25,000 sf	0.0	300.0	300.0	300.0	300.0	300.0
Storage/unfinished: 5,000 sf	0.0	60.0	60.0	60.0	60.0	60.0
Add'l space for new activities	0.0	240.0	240.0	240.0	240.0	240.0
less revenue from sublet	0.0	(120.0)	(120.0)	(120.0)	(120.0)	(120.0)

	Year Ending December 31,					
EXPENSES	1987	1988	1989	1990	1991	1992
OFFICE EQUIPMENT & FURNISHINGS	0.0	50.4	64.2	78.0	78.0	78.0
$2,000 furn/person, 7 yr life	0.0	10.9	13.9	16.9	16.9	16.9
$20,000 conf/lounges	0.0	2.9	2.9	2.9	2.9	2.9
2 eng work sta/group @$15K, 3 yr life	0.0	30.0	40.0	50.0	50.0	50.0
1 pc/mgmt staff and /group @$2,500, 3 yr life	0.0	6.7	7.5	8.3	8.3	8.3
OFFICE SUPPLIES: $250/person/yr.						
EQUIPMENT SERVICE: 7.5% lab equip cost (range = 5-10%) + 1% clean room cost						
ADDITIONAL UTILITIES,USER CHARGES	0.0	198.0	264.0	330.0	330.0	330.0
Mainframe computer user charges 80 hrs/grp/yr @$200/cpu hr	0.0	48.0	64.0	80.0	80.0	80.0
Utilities - $3-5/square foot/yr	0.0	150.0	200.0	250.0	250.0	250.0
INSURANCE	0.3	21.8	22.6	23.4	23.4	23.4
Property insurance: $.10/$100	0.0	17.0	17.0	17.0	17.0	17.0
Gen'l liability: $1/$1000 budget	0.2	3.9	4.4	4.9	4.9	4.9
Fidelity bond: $25/employee	0.1	1.0	1.2	1.5	1.5	1.5
LEGAL AND PROFESSIONAL SERVICES	37.5	75.0	75.0	75.0	75.0	75.0
Legal	25.0	50.0	50.0	50.0	50.0	50.0
Accounting and auditing	6.3	12.5	12.5	12.5	12.5	12.5
Other	6.3	12.5	12.5	12.5	12.5	12.5
JOURNALS AND REFERENCE MATERIALS	11.3	20.0	10.0	10.0	10.0	10.0
Books	7.5	12.5	2.5	2.5	2.5	2.5
Journals (25@$100)	1.3	2.5	2.5	2.5	2.5	2.5
On-line search service	2.5	5.0	5.0	5.0	5.0	5.0
PUBLICATIONS AND COMMUNICATIONS	2.5	15.0	20.0	25.0	25.0	25.0
MISCELLANEOUS: 2.5% of budget (rounded down to $10K increment)						

APPENDIX D

made prior to expiration of the disapproval period if the agency issues written notice of its intent not to disapprove the action. For purposes of this subsection (j), the term "insured bank" shall include any "bank holding company", as that term is defined in section 2 of the Bank Holding Company Act, which has control of any such insured bank, and the appropriate Federal banking agency in the case of bank holding companies shall be the Board of Governors of the Federal Reserve System.

* * *

(7) The appropriate Federal banking agency may disapprove any proposed acquisition if—

(A) the proposed acquisition of control would result in a monopoly or would be in furtherance of any combination or conspiracy to monopolize or to attempt to monopolize the business of banking in any part of the United States;

(B) the effect of the proposed acquisition of control in any section of the country may be substantially to lessen competition or to tend to create a monopoly or the proposed acquisition of control would in any other manner be in restraint of trade, and the anticompetitive effects of the proposed acquisition of control are not clearly outweighed in the public interest by the probable effect of the transaction in meeting the convenience and needs of the community to be served;

* * *

(16) This subsection shall not apply to a transaction subject to section 3 of the Bank Holding Company Act of 1956 (12 U. S. C. 1842) or section 18 of this Act (12 U. S. C. 1828). This subsection shall not apply to an insured Federal savings bank. [November 10, 1978, Public Law 95-630, Sec. 602, 92 Stat. 3683; October 15, 1982, Public Law 97-320, Sec. 113(q), 96 Stat. 1475; 12 U. S. Code, Sec. 1817.]

NATIONAL COOPERATIVE RESEARCH ACT OF 1984

[¶ 27,080]

(Act of October 11, 1984, Public Law 98-462.)

[¶ 27,081] SHORT TITLE

Section 1. This Act may be cited as the "National Cooperative Research Act of 1984". [October 11, 1984, Public Law 98-462.]

[¶ 27,082] DEFINITIONS

Sec. 2. (a) For purposes of this Act:

(1) The term "antitrust laws" has the meaning given it in subsection (a) of the first section of the Clayton Act (15 U. S. C. 12), except that such term includes section 5 of the Federal Trade Commission Act (15 U. S. C. 45) to the extent that such section 5 applies to unfair methods of competition.

(2) The term "Attorney General" means the Attorney General of the United States.

(3) The term "Commission" means the Federal Trade Commission.

(4) The term "person" has the meaning given it in subsection (a) of the first section of the Clayton Act (15 U. S. C. 12(a)).

(5) The term "State" has the meaning given it in section 4G(2) of the Clayton Act (15 U. S. C. 15g(2)).

(6) The term "joint research and development venture" means any group of activities, including attempting to make, making, or performing a contract, by two or more persons for the purpose of—

(A) theoretical analysis, experimentation, or systematic study of phenomena or observable facts,

(B) the development or testing of basic engineering techniques,

(C) the extension of investigative findings or theory of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, prototypes, equipment, materials, and processes,

(D) the collection, exchange, and analysis of research information, or

(E) any combination of the purposes specified in subparagraphs (A), (B), (C), and (D),

and may include the establishment and operation of facilities for the conducting of research, the conducting of such venture on a protected and proprietary basis, and the prosecuting of applications for patents and the granting of licenses for the results of such venture, but does not include any activity specified in subsection (b).

(b) The term "joint research and development venture" excludes the following activities involving two or more persons:

(1) exchanging information among competitors relating to costs, sales, profitability, prices, marketing, or distribution of any product, process, or service that is not reasonably required to conduct the research and development that is the purpose of such venture,

(2) entering into any agreement or engaging in any other conduct restricting, requiring, or otherwise involving the production or marketing by any person who is a party to such venture of any product, process, or service, other than the production or marketing of proprietary information developed through such venture, such as patents and trade secrets, and

(3) entering into any agreement or engaging in any other conduct—

(A) to restrict or require the sale, licensing, or sharing of inventions or developments not developed through such venture, or

(B) to restrict or require participation by such party in other research and development activities,

that is not reasonably required to prevent misappropriation of proprietary information contributed by any person who is a party to such venture or of the results of such venture. [October 11, 1984, Public Law 98-462.]

[¶ 27,083] RULE OF REASON STANDARD

Sec. 3. In any action under the antitrust laws, or under any State law similar to the antitrust laws, the conduct of any person in making or performing a contract to carry out a joint research and development venture shall not be deemed illegal per se; such conduct shall be judged on the basis of its reasonableness, taking into account all relevant factors affecting competition, including, but not limited to, effects on competition in properly defined, relevant research and development markets. [October 11, 1984, Public Law 98-462.]

[¶ 27,084] LIMITATION ON RECOVERY

Sec. 4. (a) Notwithstanding section 4 of the Clayton Act (15 U. S. C. 15) and in lieu of the relief specified in such section, any person who is entitled to recovery on a claim under such section shall recover the actual damages sustained by such person, interest calculated at the rate specified in section 1961 of title 28, United States Code, on such actual damages as specified in subsection (d), and the cost of suit attributable to such claim, including a reasonable attorney's fee pursuant to section 5 of this Act if such claim—

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(1) results from conduct that is within the scope of a notification that has been filed under section 6(a) of this Act for a joint research and development venture, and

(2) is filed after such notification becomes effective pursuant to section 6(c) of this Act.

(b) Notwithstanding section 4C of the Clayton Act (15 U. S. C. 15c), and in lieu of the relief specified in such section, any State that is entitled to monetary relief on a claim under such section shall recover the total damage sustained as described in subsection (a)(1) of such section, interest calculated at the rate specified in section 1961 of title 28, United States Code, on such total damage as specified in subsection (d), and the cost of suit attributable to such claim, including a reasonable attorney's fee pursuant to section 4C of the Clayton Act if such claim—

(1) results from conduct that is within the scope of a notification that has been filed under section 6(a) of this Act for a joint research and development venture, and

(2) is filed after such notification becomes effective pursuant to section 6(c) of this Act.

(c) Notwithstanding any provision of any State law providing damages for conduct similar to that forbidden by the antitrust laws, any person who is entitled to recovery on a claim under such provision shall not recover in excess of the actual damages sustained by such person, interest calculated at the rate specified in section 1961 of title 28, United States Code, on such actual damages as specified in subsection (d), and the cost of suit attributable to such claim, including a reasonable attorney's fee pursuant to section 5 of this Act if such claim—

(1) results from conduct that is within the scope of a notification that has been filed under section 6(a) of this Act for a joint research and development venture, and

(2) is filed after notification has become effective pursuant to section 6(c) of this Act.

(d) Interest shall be awarded on the damages involved for the period beginning on the earliest date for which injury can be established and ending on the date of judgment, unless the court finds that the award of all or part of such interest is unjust in the circumstances.

(e) This section shall be applicable only if the challenged conduct of a person defending against a claim is not in violation of any decree or order, entered or issued after the effective date of this Act, in any case or proceeding under the antitrust laws or any State law similar to the antitrust laws challenging such conduct as part of a joint research and development venture. [October 11, 1984, Public Law 98-462.]

[¶ 27,085] ATTORNEY'S FEES

Sec. 5. (a) Notwithstanding sections 4 and 16 of the Clayton Act, in any claim under the antitrust laws, or any State law similar to the antitrust laws, based on the conducting of a joint research and development venture, the court shall, at the conclusion of the action—

(1) award to a substantially prevailing claimant the cost of suit attributable to such claim, including a reasonable attorney's fee, or

(2) award to a substantially prevailing party defending against any such claim the cost of suit attributable to such claim, including a reasonable attorney's fee, if the claim, or the claimant's conduct during the litigation of the claim, was frivolous, unreasonable, without foundation, or in bad faith.

(b) The award made under subsection (a) may be offset in whole or in part by an award in favor of any other party for any part of the cost of suit, including a reasonable attorney's fee, attributable to conduct during the litigation by any prevailing party that the court finds to be frivolous, unreasonable, without foundation, or in bad faith.

[¶ 27,086] DISCLOSURE OF JOINT RESEARCH AND DEVELOPMENT VENTURE

Sec. 6. (a) Any party to a joint research and development venture, acting on such venture's behalf, may, not later than 90 days after entering into a written agreement to form such venture or not later than 90 days after the date of the enactment of this Act, whichever is later, file simultaneously with the Attorney General and the Commission a written notification disclosing—

(1) the identities of the parties to such venture, and

(2) the nature and objectives of such venture.

Any party to such venture, acting on such venture's behalf, may file additional disclosure notifications pursuant to this section as are appropriate to extend the protections of section 4. In order to maintain the protections of section 4, such venture shall, not later than 90 days after a change in its membership, file simultaneously with the Attorney General and the Commission a written notification disclosing such change.

(b) Except as provided in subsection (e), not later than 30 days after receiving a notification filed under subsection (a), the Attorney General or the Commission shall publish in the Federal Register a notice with respect to such venture that identifies the parties to such venture and that describes in general terms the area of planned activity of such venture. Prior to its publication, the contents of such notice shall be made available to the parties to such venture.

(c) If with respect to a notification filed under subsection (a), notice is published in the Federal Register, then such notification shall operate to convey the protections of section 4 as of the earlier of—

(1) the date of publication of notice under subsection (b), or

(2) if such notice is not so published within the time required by subsection (b), after the expiration of the 30-day period beginning on the date the Attorney General or the Commission receives the applicable information described in subsection (a).

(d) Except with respect to the information published pursuant to subsection (b)—

(1) all information and documentary material submitted as part of a notification filed pursuant to this section, and

(2) all other information obtained by the Attorney General or the Commission in the course of any investigation, administrative proceeding, or case, with respect to a potential violation of the antitrust laws by the joint research and development venture with respect to which such notification was filed, shall be exempt from disclosure under section 552 of title 5, United States Code, and shall not be made publicly available by any agency of the United States to which such section applies except in a judicial or administrative proceeding in which such information and material is subject to any protective order.

(e) Any person who files a notification pursuant to this section may withdraw such notification before notice of the joint research and development venture involved is published under subsection (b). Any notification so withdrawn shall not be subject to subsection (b) and shall not confer the protections of section 4 on any person with respect to whom such notification was filed.

(f) Any action taken or not taken by the Attorney General or the Commission with respect to notifications filed pursuant to this section shall not be subject to judicial review.

(g)(1) Except as provided in paragraph (2), for the sole purpose of establishing that a person is entitled to the protections of section 4, the fact of disclosure of conduct under section 6(a) and the fact of publication of a notice under section 6(b) shall be admissible into evidence in any judicial or administrative proceeding.

(2) No action by the Attorney General or the Commission taken pursuant to this section shall be admissible into evidence in any such proceeding for the purpose of supporting or answering any claim under the antitrust laws or under any State law similar to the antitrust laws. [October 11, 1984, Public Law 98-462.]

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